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DISCUSSION OF THE DESIGN OF SATELLITE-LASER MEASUREMENT STATIONS IN THE EASTERN MEDITERRANEAN UNDER THE GEOLOGICAL ASPECT

CONTRIBUTION TO THE EARTHQUAKE PREDICTION RESEARCH BY THE WEGENER GROUP AND TO NASA'S CRUSTAL DYNAMICS PROJECT

Dr. A. Paluska and Dr. N. Pavoni

Translation of "Erlaeuterung zum Entwurf der Satelliten-Laser-Messtationen (SLR) im Oestlichen Mittelmeerraum aus Geologischer Sicht; Beitrag zur Erdbebenvorhersageforschung der WEGENER Gruppe und zum Crustal Dynamics Project der NASA", August, 1983, pages 1-17.

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16. Abstract

The article discusses the research conducted for the purpose of determining the position of measurement stations for crustal dynamics for the purpose of earthquake prediction, describes the procedural aspects, the extraregional kinematic tendencies and regional tectonic deformation mechanisms.

*EARTHQUAKE PREDICTION RESEARCH BY THE WEGENER GROUP AND TO NASA'S CRUSTAL DYNAMICS PROJECT.

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DISCUSSION OF THE DESIGN OF SATELLITE-LASER MEASUREMENT STATIONS IN THE EASTERN MEDITERRANEAN UNDER THE GEOLOGICAL ASPECT

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Dr. A. Paluska and Dr. N. Pavoni

1. General /2

On the basis of geological as well as geophysical findings and considerations within the framework of the Wegener Group the first project for the location of measurement stations (laser centers) in the Eastern Mediterranean were established in March, 1981 (Paluska, 1981). This concept was thoroughly tested subsequently in particular from the point of view of the practical feasibility and finally taken with some alterations or supplements as a basis for further project planning (Ritsema and Vlaar, 1981, Van Gelder and Aardoom, 1982, Wilson, 1983, Aardoom, Van Gelder and Vermaat, 1983).

At present work is being conducted for the final version of the project and it seemed therefore convenient to discuss in greater detail than before the geological aspects on which the original project was based as well as some of the supplements and thus provide a complete update for all those taking part in the project.

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*Numbers in the margin indicate pagination in the foreign text.

2. Procedural Aspects

To select the optimum positioning of the measurement stations two factors were primarily decisive:

--extraregional kinematic tendencies (plate tectonic models) and

--regional as well as local tectonic or seismotectonic activities and deformation mechanisms (especially in the Alpine belt).

From the procedural point of view further aspects must be considered:

--the movement tendency of the selected locality should be known already in broad outlines and if possible experiments should already have been made for quantization (for example speed of movement on the North-Anatolic Fault of about 1 cm/year, Pavoni, 1961). /3

--the measurement distances (or measurement bases) should be chosen in such a way that their alterations to be expected over the next 20 years according to our present knowledge should furnish maximum amount of movement as well as a representative, kinematically relevant direction of movement.

--any such kinematic tendency should be ascertained by two measurement points so that in case of possible failure of one station it will be possible to obtain comparable values.

--the individual measurement points should be located in a favorable position as regards traffic. Because of the difficulties of supply remote areas should be avoided.

--any measurement point should be included in a network of conventional geodesic points. In this way it will be possible to obtain possible local effects.

--the direct vicinity of the measurement points must be geologically mapped before the final installation to avoid the measurement results from being affected adversely by for example, slips or any sliding movements as a consequence of for example, road excavations, vibrations from explosions in nearby stone breaking plants, local faults active in actual earthquakes, phenomena of erosion, karst formation as well as underground construction works or finely also powerful unstable disintegration profiles and not for the least fluctuations of the ground water level.

3. Extraregional Kinematic Tendencies

The concept of establishment of measurement stations described briefly below is based on the representation or quarternary and recent tectonic processes which cover the entire orogen and move it in a mobile state. The existence assumed alternately in the technical literature of so-called "microplates" (McKenzie, 1972 et al), but primarily the type of their tectonic activation (insofar as they are considered rigid elements) is on the other hand not consistent with the geological findings. A thorough discussion of this topic appears to be necessary at some later time. /4

Kinematic tendencies in the studied region are causally related according to our present knowledge with three factors:

- --with the global movement plan of the large plates which has still to be quantized individually and is still considered to a great extent mechanistically;
- --with the thermodynamic processes in the mantle, whose effect on the crust appear both in horizontal and vertical movements;
- --with extraordinarily complex map reorganizations covering a large area in the region of the Alpine belt.

Large Plates

The plan of movement of the two large plates: Eurasian and African is like a type of boundary condition. For the Eurasian plate we generally assume a movement directed towards the east and for the African one a movement directed towards the west (Pavoni, 1961, Minster and Jordan, 1978, etc.). This trend may be reflected in the shifting of a base (points Cairo/Ulad, Medenine) installed in North Africa against West Europe (the points Kootwijk and Wetzel).

This movement can at present be quantized only on the basis of the sea floor spreading rates in the Atlantic (Pitman and Talwani, 1972 etc.). According to it in the Mediterranean area we may expect speeds of the horizontal displacement between the two large plates of up to 4 cm/year (or 6-7 cm/year, Mueller, 1983). /5

Mechanisms of collision between the two large plates up to a possible subduction in the Eastern Mediterranean should be rendered perceptible by the behavior of the North African base as compared with the Greek Archipelago (points on Crete and Peloponnes).

The kinematics of the Arabian plate extraordinarily significant for the tektogenic processes in East Anatolia could not be included yet at the present time in the measurement system. This might possibly give an uncertainty in the interpretation of some measurement data.

The Aegean Area

The generally N-S oriented extent of the Aegean area along with the bordering regions represents a deformation process dating from approximately the middle Quarternary in the Alpine Belt, whose mechanisms individually as well as the causes are generally among the most difficult problems of the East Mediterranean kinematics. Among others the relation otherwise very difficult to understand between this range and the subduction assumed by some authors in the South or in the region of the Greek Archipelago has to be discussed among other things.

We expect the maximum expansion rates between the extreme south border (Crete base) and the Rhodope mass (Komotini point) and the extended Macedonian area (Point Veria) in the North.

In Western Turkey the expansion process is manifested in the disintegration of the Menderes mass into smaller blocks separated from each other by trench-like structures.

North Anatolian Horizontal Displacement /6

One of the most marked kinematic tendencies of the studied region particularly informative for seismotectonic analyses is the tectogenic activity along the North Anatolian Fault. This is a horizontal displacement in which the Northern (pontic) Block with the Rhodope and Istranca mass drifts relatively eastward, whereas the Southern (Anatolian)

Block moves against it towards the West. The relative speed of this movement is estimated at about 1 cm/year (Pavoni, 1961).

A reliable picture of the kinematic very different both in space and time should be obtained from the arrangement of the points Bursa and Isklip in the south and Komotini and Bolu in the North of the fault zone up to 10-20 km wide.

The North Anatolian horizontal movement meets with the Vardar Fault trough in the West. Measurements at the point barrier should clarify how far these two structural elements are connected and how far the same tendency to movement can be assigned to them.

To obtain at least in broad outlines information about the eastern continuation in the area of the East Anatolian Fault, a measurement point is proposed at Diyarbakir in East Turkey. We are naturally aware that this program is in no way sufficient to assure a satisfactory interpretation of the measurement data.

Pindos and Gavrovo Zone

The southern continuations of the Dinarides on the Balkan in the area of the Pindos and Gavrovo Region show partly intense concentration structures and phenomena, whose recent activity can be related only with difficulty with the expansion processes in the Aegean and therefore requires thorough study. For this purpose the points Argostolion and Veria and also Sparta are proposed.

4. Regional Tectonic Deformation Mechanisms /7

With reference to the direction of movement and the speed of movement, regional or even local tectonic deformation mechanisms mostly in the form of individual events (for example earthquakes, volcanic activity) should have at least temporarily, occasionally also over longer periods (for example sliding of large rock layers) have a greater intensity than the extraregional kinematic tendencies mentioned in Chapter 3. These phenomena include primarily:

--The special material dependent mechanical behavior of different rock masses and formations in the corresponding extraregional strip field. In other words: the capacity of the rock to store, transmit or break up stresses. These include for example folding processes, expansions of yielding materials, formation of breaks in brittle material etc.

--Lateral mass reorganizations caused by vertical earth crust movements (elevations and descents) controlled to a great extent by forces of gravity (Paluska and Degens, 1979).

--Thrust deformation mechanisms in the broadest sense (phenomena of dilitation, formation of thrust structures, Paluska et al., 1982).

Under this aspect the masses which are preferably consolidated, consist as far as possible of crystalline rocks and therefore behaving more or less passively within the corresponding origin (Rhodope, Menderez, Istranca mass) come into consideration for locating the measurement points, also younger tectonically undisturbed formations (for example plateaus consisting of mesozoic or tertiary rocks).

The location of measurement points in regions of high tectonic mobility mostly with an intensely differentiated kinematic plan raises necessarily the danger that the extraregional tectonic plan would be /8
affected by local movement tendencies and thus would not be identified or at least not correctly nor in the full extent.

5. Position of the Measurement Station

The sequence of the measurement stations discussed briefly below correspond in their priority more or less to the measurement program under discussion.

Measurement Points of High Priority

Cairo Station, Northeast Egypt

Coordinates: 31 degrees 10 minutes (East) and 30 degrees 05 minutes (North)

Altitute of about 50 - 100 m above mean sea level.

In the entire measurement system this station represents with the point Ulad or alternately Medenine the kinematics of the African plate. Therefore it should show a tendency to movement directed westward with regard to the Eurasian plate.

A more exact location could not be obtained so far. Presumably the station will be installed on the older tertiary sediments which have hardly been disturbed tectonically.

Ulad Station, Northwest Egypt

Coordinates: 27 degrees 10 minutes (East) and 31 degrees 30 minutes (North)

Altitude of about 100 to 200 m above mean sea level.

Ulad is a hill near the Egyptian-Libyan border. The measurement station proposed is the site of Matruh (port on the Mediterranean Coast).

The station is needed to establish a measurement basis on the African plate. At the same time it provides security for the station Cairo or Medenine. It will most probably show the same movement tendency as both of them.

The underground of the region is formed of oligomyocene, tectonically hardly disturbed sediments.

Station Medenine, South Tunesia. /9

Coordinates: 10 degrees 30 minutes (East) and 33 degrees 30 minutes (North)

Altitude about 100 m above sea level.

If the erection of one of the two Egyptian stations should prove to be unfeasible, the measurement base can be established on the African plate through an Egyptian and a Tunisian point.

The measurement station is proposed in the neighborhood of the site Medenine in South Tunesia in the area of the Ksour Hill. This region is accessible from the road from the port of Gabes on the Mediterranean coast.

The underground is formed by tectonically hardly disturbed cretacean deposits.

Matera Station, Southern Appennines, Italy.
Coordinates: 16 degrees 40 minutes (East) and 40 degrees 40 minutes (North).
Altitude about 500 m above mean sea level.

The final site Matera is accessible from the ports of Bari (about 60 km) and Brindisi (about 140 km). The station should allow a connection of the measurement system in the Southern Appennines and clarify the tendency to movement in the region of the Ionic Sea.

The underground is formed of upper cretacean sediments.

Station Sitia, Eastern Crete, Greece.
Coordinates: 26 degrees 15 minutes (East) and 35 degrees 10 minutes (North).
Altitude about 200 - 500 m above sea level.

The site of Sitia is a small port on the coast of Eastern Crete. It is accessible by ship directly from Pireus or from Iraklion, or by road from Iraklion to Ajios Nikolaos.

A site on the eastern coast near the regions of Palaekastron and Sakros was proposed for the measurement stations. The relative movement of this point with regard to the stations of the African plate is very important. The narrowing of the Eastern Mediterranean area would indicate a collision mechanism and therefore subduction, expansion between the large two plates, on the other hand the occurrence of the /10 trough structure south of Crete would be explained by depression.

The geological underground is formed by cretacean sediments, strongly disturbed tectonically in part.

Komotini Station, Thracian region, Greece.

Coordinates: 26 degrees 00 (East) and 41 degrees 20 minutes (North).

Altitude about 500 - 1000 m above sea level.

The final site Komotini is accessible from the point of Kavala by road in the direction of Xanthi. The measurement station is proposed to lie about 25 km east of Komotini between the areas of Organi and Myrtiski.

Along with the point Veria the measurements at the station of Komotini should cover on one hand the opening of the Vardar Fault trough. On the other hand the points of Komotini and Bolu should form a base north of the North Anatolian Fault zone which could indicate a movement tendency with regard to the southern flank towards the East.

The region around Komotini is part of the Rhodope mass and consists of metamorphic precambrian rocks (gneiss).

Bursa station, West Anatolia, Turkey.

Coordinates: 29 degrees 05 minutes (East) and 40 degrees 10 minutes (North).

Altitude about 1000 m above sea level.

The city of Bursa (final point) lies about 90 km south of Istanbul. From there it is accessible by road to Izmit, Yalova and Gemlik.

The measurement station proposed will lie about 20 km south of Bursa in the region of the Uludag mass. Here it will be located on the southern flank of the North Anatolian Fault zone and together with the station Isklip it will represent a base with relative movement of tendency towards the West, as compared with the Northern flank. Moreover with the point Mugla it will be used to record the crust expansion in West Turkey.

Mugla Station, Southwest Turkey. /11

Coordinates: 20 degrees 20 minutes (East) and 37 degrees 15 minutes (North).

Altitude about 500 - 1000 m above sea level.

The Mugla site is accessible by road from Marmaris (port with ship connection to Piraeus). The measurement station lies on the southern border of the Menderez mass, whose eastern part today manifests a high seismic activity. The measurement distance Mugla - Bursa should cover the expansion process of the crust in Western Turkey.

The station lies on mesozoic to older tertiary rocks.

Station of Argostolion, Island of Kefallinia, Greece.

Coordinates: 20 degrees 40 minutes (East) and 38 degrees 10 minutes (North).

Altitude about 500 - 1000 m above sea level.

The site of Argostolion lies at the Southern coast of the island. It has an airport and is moreover accessible by road from Sami (port). Here there is a connection by ship with Piraus andBrindisi. The measurement station is proposed to be built near the above mentioned connection road to Sami. Just like the point of Sparta it should provide

information on possible causes of the high seismic activity on the northern age of the Ionic trough.

Measurement Points of Average Priority

Veria (also Veroia) Station, Macedonia, Greece.

Coordinates: 22 degrees 00 minutes (East) and 40 degrees 30 minutes (North).

Altitude about 500 - 1000 m above sea level.

The site of Veria is about 80 km west of Thessaloniki in the direction of the Chantova Pass. The measurement station is proposed to be built about 20 km north of Veria near the region of Nausa (also Naousa).

It lies on the southern flank of the Vardar Fault trough. Along with the measurements in Komotini it should clarify the activity of the trough in regard to the movements of the North Anatolian Fault zone.

The underground is formed of metamorphic mesozoic rocks.

Station of Komymvarion, Western Crete, Greece. /12

Coordinates: 23 degrees 40 minutes (East) and 35 degrees 30 minutes (North).

Altitude about 200 to 500 m above sea level.

Kolymvarion and Kastellion are sites on the Western coast of Crete. Both are being considered as the final sites. They are accessible by road from Iraklion, Suda and Chania. The port of Suda maintains a connection by ship with Piraeus.

The measurement station is proposed to lie near the area of Platanos. It provides safety for the station Sitia, with which it should show the same kinematic tendencies.

The underground consists of metamorphic mesozoic deposits.

Bolu Station, Central Anatolia, Turkey.

Coordinates: 32 degrees 00 minutes (East) and 41 degrees 00 minutes (north).

Altitude about 500 - 100 m above sea level.

The final site Bolu is accessible from Istanbul by road to Izmit and Adapazari. The measurement station proposed is to be built north-east of Bolu on the road to Zomguldag near the area of Kaynarcahani.

It belongs to the Bolu-Komotini Base which should cover the movement directed eastward (relative to the Southern flank) of the Northern flank of the North Anatolian Fault zone.

The underground consists of crystalline rocks (predominately granite).

Isklip Station, Central Anatolia, Turkey.

Coordinates: 34 degrees 30 minutes (East) and 40 degrees 45 minutes (North).

Altitude about 1000 m above sea level.

The site of Isklip is accessible from the final site Corum by road from Ankara to Samsun (port on the Black Sea coast). The proposed measurement station at Isklip is about 60 km northwest of Corum. Together with the point Bursa it forms a base on the Southern flank of the North Anatolian Fault zone and may show a tendency of movement westward. /13

Eocenic vulcanite and flysch occur in the neighborhood of Isklip.

Measurement Points of Low Priority

Diyarbakir Station, East Anatolia, Turkey.

Coordinates: 40 degrees 20 minutes (East) and 37 degrees 50 minutes (North).

Altitude about 500 - 1000 m above sea level.

The site of Diyarbakir is accessible from the fort of Mersin on the Mediterranean coast by road to Adana and Malatya. The exact position of the measurement station was not yet established. It may be located east of the East Anatolian Fault and contribute to the clarification of its kinematics.

The region around Diyarbakir consists of younger tertiary and quarternary vulcanites.

Sparta Station, Peloponnes, Greece.

Coordinates: 22 degrees 15 minutes (East) and 37 degrees 10 minutes (North).

Altitude about 500 - 1000 m above sea level.

Sparta is proposed as a final site because of the favorable traffic connections. The measurement station should be installed near the road from Kalamata (port) to Sparta, say between the areas of Trypi and Artemsia. It lies in the neighborhood of the section of the Ionic Trench 9also Hellenic Trench), in which at present intense seismic activity was recorded. Information on the causes of this activity can be obtained from the variations of position with regard to the Matera Station.

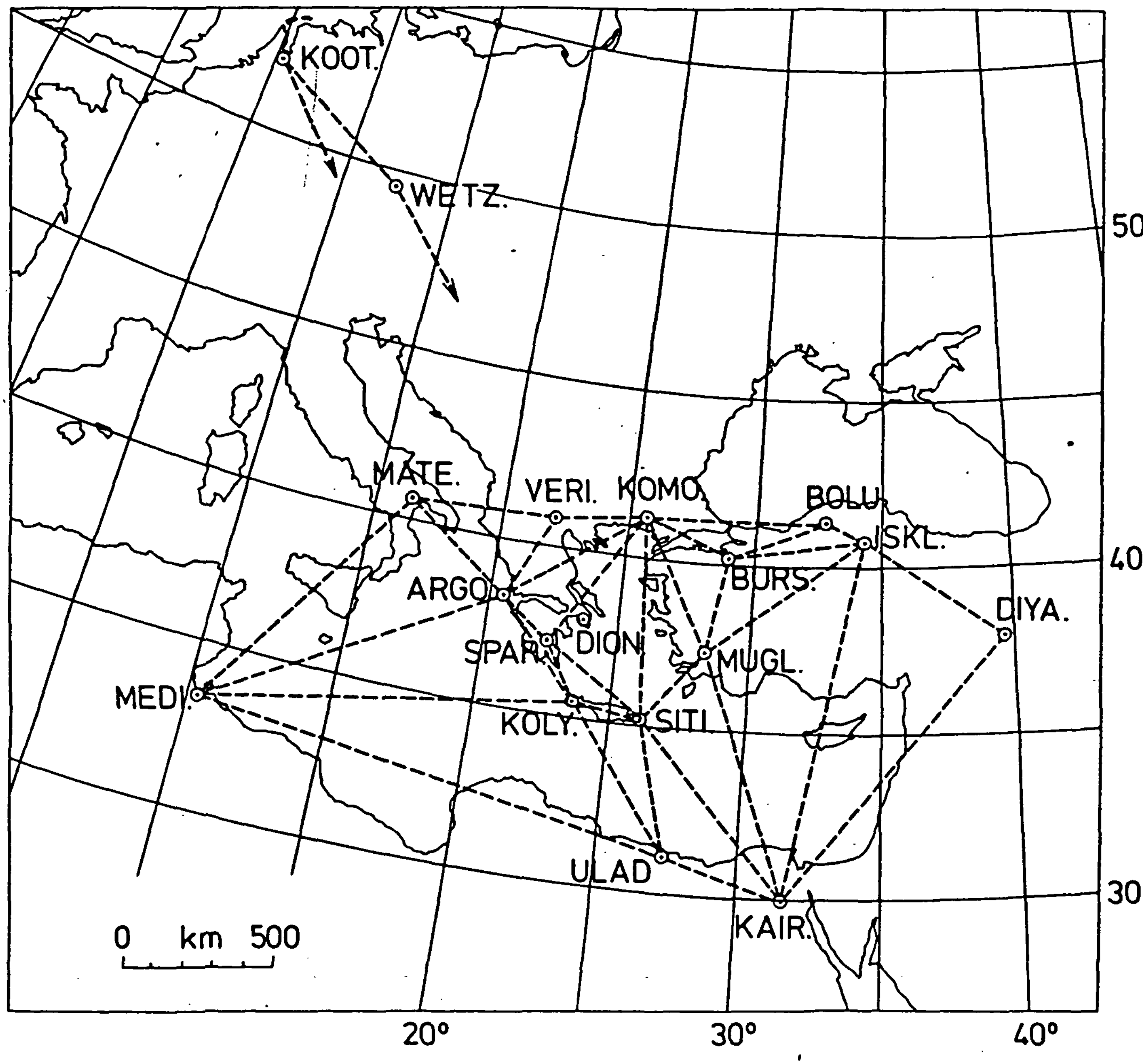
The underground consists of metamorphic mesozoic rocks.

Station Dionysos, Greece. /14

Coordinates: 23 degrees 56 minutes (East) and 38 degrees 05 minutes (North).

Altitude about 200 - 500 m above sea level.

As compared with the above mentioned measurement station this point lying near Athens has no special relevance with regard to kinematic tendencies in the Eastern Mediterranean region. Its function in the overall measurement system is more or less comparable with the point Veria and with Sparta also with some limitations.



Plan of the Satellite Laser Measurement Stations in the Eastern Mediterranean Region. Dr. Paluska and Dr. Pavoni.

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